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MOTOR VEHICLE HAVING AN OCCUPANT PROTECTION SYSTEM

The present invention relates to a motor vehicle having an occupant protection system or an occupant protection device, such as an airbag.

Airbag systems are described, for example, in the article "Hardware and Mechanics of Real Airbag Control Systems" published on the Internet page www.informatik.uni-dortmund.de/airbag/seminarphase/hardware_vortrag.pdf.

U.S. 5,583,771, U.S. 5,684,701, and U.S. 6,532,508 B1 describe the triggering of an airbag by a neural network as a function of an output signal of an acceleration sensor.

DE 198 54 380 A1 describes a method for detecting the severity of a vehicle collision, where the output signals of a plurality of acceleration sensors are supplied to a neural network. In the method, the start of the evaluation of the acceleration-sensor output signals is determined by a trigger signal, which is output by an acceleration sensor when its output signal exceeds a predefined threshold value. This acceleration sensor causes the other acceleration sensors to supply the respective output signal at one and the same time. It is also provided that the output signals of the acceleration sensors be integrated one or two times.

DE 100 35 505 A1 describes a method, in which the future time characteristic of the output signal of an acceleration sensor is predicted with the aid of a neural network on the basis of the acceleration-sensor signals at at least one defined time.

DE 100 40 111 A1 describes a method for producing a triggering decision for restraining devices in a vehicle, where the

difference of measured acceleration values is calculated and the magnitude of the difference is subsequently integrated. The integral is compared to at least one threshold value. If the integral does not exceed this threshold value by a predefined time, then the position of a triggering threshold for the measured acceleration or for a speed change derived from it is modified in such a manner, that the triggering sensitivity becomes lower.

Described in DE 101 03 661 C1 is a method for sensing lateral impact in a motor vehicle; acceleration sensors, from whose output signals the difference is calculated, being situated on the left and right sides of the vehicle. The differential acceleration signal is integrated or summed up. For the purpose of side-impact sensing, the differential speed signal is compared to a threshold value, which is calculated as a function of the differential acceleration signal.

The object of the present invention is to provide a motor vehicle that is improved with regard to occupant protection.

The above-mentioned object is achieved by a motor vehicle having at least one first crash sensor situated in a safety zone of the motor vehicle, for measuring a motion variable of the motor vehicle, and having at least one second crash sensor situated in a crash zone of the motor vehicle, for measuring a (further) or the same motion variable of the motor vehicle; the motor vehicle including an occupant detection device controllable via an ignition signal, and a control unit for ascertaining the ignition signal as a function of the measured motion variables and/or, in each instance, as a function of a time average of the measured motion variables over at least one time interval.

A crash zone of the motor vehicle within the meaning of the present invention is, in particular, a region of the motor vehicle which, in the event of a collision of the motor vehicle with an obstacle, can be destroyed prior to a (setpoint) triggering time of the occupant protection device. A safety zone of the motor vehicle within the meaning of the present invention is, in particular, a region of the motor vehicle which, in the event of a collision of the motor vehicle with an obstacle, is not destroyed or is destroyed after a (setpoint) triggering time of the occupant protection device.

An occupant protection device within the meaning of the present invention is, in particular, an airbag and/or a belt tensioner. A motion variable of the motor vehicle within the meaning of the present invention may be an acceleration, a speed, or a displacement, or a variable derived from these variables.

A crash sensor within the meaning of the present invention may be an acceleration sensor for measuring an acceleration in one or more directions. A crash sensor within the meaning of the present invention may also be a radar device, an infrared set-up, or a camera. In this case, a motion variable of the motor vehicle may be a distance of the motor vehicle from an obstacle, the first or second derivative of this distance, or another equivalent variable. A crash sensor within the meaning of the present invention may also be a sensor for measuring a deformation of the motor vehicle. Such a sensor may be a fiber-optic sensor or a sensor described in DE 100 16 142 A1. In this case, a motion variable of the motor vehicle may be a deformation of the motor vehicle, the first or second derivative of this deformation, or another equivalent variable.

A time average within the meaning of the present invention may be an arithmetic mean or a weighted average. In the case of such a weighted average, e.g. more recent values of the motion variable in the relevant time interval may be more heavily weighted than older values of the motion variable in the relevant time interval. An average value within the meaning of the present invention may also be a value proportional to an average value. In an advantageous refinement of the present invention, the average value is a value proportional to the arithmetic mean. In this context, the average value is advantageously a value proportional to the integral of the motion variable in the relevant time interval or a value proportional to the sum of sampled values of the motion variable in the relevant time interval.

An ignition signal within the meaning of the present invention may be a binary signal, which indicates if an occupant protection device, such as an airbag and/or a belt tensioner, should be triggered. Such an ignition signal within the meaning of the present invention may be a "FIRE/NO-FIRE" signal described in DE 100 35 505 Al. An ignition signal within the meaning of the present invention may also be a more complex signal, which indicates the degree (e.g. stage 1 or stage 2) to which an airbag should be fired. In addition, such an ignition signal within the meaning of the present invention may be a crash-severity parameter or an occupant acceleration or loading described in DE 100 35 505 A1. An ignition signal within the meaning of the present invention may be, or include, an information item indicating the location and/or the direction of a collision.

In an advantageous refinement of the present invention, the first crash sensor and the second crash sensor are situated at least 0.5 m away from each other. In a further advantageous refinement of the present invention, the first crash sensor is

connected to the control unit, integrated into the control unit, or situated in a housing with the control unit.

In a further advantageous refinement of the present invention, the control unit includes

- at least one first triggering relationship for ascertaining the ignition signal as a function of the measured motion variables and/or, in each instance, as a function of a time average of the measured motion variables over the at least first time interval; and/or
- at least one second triggering relationship for ascertaining the ignition signal as a function of the motion variable measured by the first crash sensor and/or as a function of its time average over the at least first time interval, but not as a function of the motion variable measured by the second crash sensor and/or not as a function of its time average over the at least first time interval.

In a further advantageous refinement of the present invention, the control unit includes a selection module for selecting the first triggering relationship or the second triggering relationship for instantaneously ascertaining the ignition signal, the selection between the second triggering relationship and the first triggering relationship being made, in particular, as a function of the motion variable measured by the second crash sensor and/or as a function of its time average over the at least first time interval.

In a further advantageous refinement of the present invention, the ignition signal is also ascertainable as a function of a time average of the motion variable measured by the first crash sensor, over a second time interval that is different from the first time interval. Within the meaning of the

present invention, a second time interval different from a first time interval may differ from the first time interval in its length and/or its position.

In a further advantageous refinement of the present invention, the first time interval and/or the second time interval is between 1 ms and 200 ms long, in particular between 4 ms and 32 ms long, and advantageously between 8 ms and 24 ms long.

In a further advantageous refinement of the present invention, the first time interval and/or the second time interval are staggered by between 1 ms and 50 ms, and advantageously by between 2 ms and 16 ms.

The above-mentioned object is additionally achieved by a method for manufacturing a motor vehicle, in particular a motor vehicle having one or more of the above-mentioned features, at least one first crash sensor for measuring a motion variable of the motor vehicle being situated in a safety zone of the motor vehicle, at least one second crash sensor for measuring a motion variable of the motor vehicle being situated in a crash zone of the motor vehicle, and an occupant detection device controllable via an ignition signal and a control unit for ascertaining the ignition signal as a function of the measured motion variables and/or, in each instance, as a function of a time average of the measured motion variables over at least one first time interval, being situated in the motor vehicle.

In one advantageous refinement of the present invention,

- at least one first triggering relationship for ascertaining the ignition signal as a function of the measured motion variables and/or, in each instance, as a function of a time average of the measured motion variables over the at least first

time interval is generated (and, in particular, implemented in the control unit); and/or

- at least one second triggering relationship for ascertaining the ignition signal as a function of the motion variable measured by the first crash sensor and/or as a function of its time average over the at least first time interval, but not as a function of the motion variable measured by the second crash sensor and/or not as a function of its time average over the at least first time interval, is generated (and, in particular, implemented in the control unit).

In a further advantageous refinement of the present invention, the first triggering relationship and/or the second triggering relationship is generated (in particular, automatically) as a plurality of comparisons of the motion variables and/or their time averages over the at least first time interval and/or over at least the first time interval and a second time interval different from the first time interval, to a plurality of limiting values.

In a further advantageous refinement of the present invention, the limiting values are automatically determined, the number of comparisons is automatically determined, the order of the comparisons is automatically selected, a measured motion variable and/or its time average over the at least first time interval and/or over the at least first time interval and the second time interval is automatically selected for a comparison, and/or the age of the motion variables and/or of the time averages over the at least first time interval and/or over the at least first time interval and the second time interval is automatically selected for the comparisons.

In a further advantageous refinement of the present invention, the first triggering relationship and/or the second triggering relationship is generated as a function of the measured motion variable or its time average over the at least first time interval and/or over at least the first time interval and the second time interval of a situation, for which a setpoint triggering time of the occupant protection device is known, but the measured motion variable or its time average over the at least first time interval and/or over at least the first time interval and the second time interval being disregarded in a training-suppression time interval prior to the setpoint triggering time of the occupant protection device, around the setpoint triggering time of the occupant protection device, or after the setpoint triggering time of the occupant protection device, during the generation of the first triggering relationship and/or the second triggering relationship.

In a further advantageous refinement of the present invention, the measured motion variable and/or its time average over the at least first time interval and/or over the at least first time interval and the second time interval is disregarded in a training-suppression time interval prior to the setpoint triggering time of the occupant protection device, when the first triggering relationship and/or the second triggering relationship is generated.

In a further advantageous refinement of the present invention, the training-suppression time interval is between 1 ms and 40 ms long, in particular between 2 ms and 10 ms long, and advantageously approximately 5 ms long.

A motor vehicle in the sense of the present invention is, in particular, a land vehicle that may be used individually in road traffic. In particular, motor vehicles in the sense of

the present invention are not restricted to land vehicles having an internal combustion engine.

Further advantages and details are derived from the following description of exemplary embodiments, objects that are identical or substantially identical being denoted by the same reference numerals. The figures show:

Fig. 1 a plan view of a motor vehicle;

Fig. 2 an exemplary embodiment of an occupant protection system;

Fig. 3 an exemplary embodiment of a control module;

Fig. 4 an exemplary embodiment of a triggering module;

Fig. 5 an exemplary embodiment of an output signal of a crash sensor;

Fig. 6 the integral of the output signal of Fig. 5, in a time interval;

Fig. 7 an exemplary embodiment of a trigger generator;

Fig. 8 an exemplary embodiment of a neural network;

Fig. 9 an exemplary embodiment of a decision tree;

Fig. 10 an exemplary embodiment of a method for manufacturing a motor vehicle;

Fig. 11 the integral according to Fig. 6, having a training-suppression time interval;

Fig. 12 a section of the integral according to Fig. 11;

Fig. 13 a triggering information item having a training-suppression time interval;

Fig. 14 a section of the integral according to Fig. 6;

Fig. 15 a further triggering information item having a training-suppression time interval;

Fig. 16 a further exemplary embodiment of a triggering module;

Fig. 17 a further exemplary embodiment of a triggering module; and

Fig. 18 a further exemplary embodiment of a triggering module.

Fig. 1 shows a plan view of a motor vehicle 1 having an occupant protection system, which is represented in Fig. 2 in the form of a block diagram. The occupant protection system includes at least one airbag 15, which is not represented in Fig. 1 but rather in Fig. 2, and/or a belt tensioner 16, which is not represented in Fig. 1 but rather in Fig. 2. The occupant protection system additionally includes a control unit 2 for triggering airbag 15 and/or belt tensioner 16, as well as a crash sensor S2 integrated into the right front end of motor vehicle 1 and a crash sensor S3 integrated into the left front end of motor vehicle 1. Crash sensors S2 and S3 are connected to control unit 2 by leads 5 and 6.

Crash sensors S2 and S3, as well as an additional crash sensor S1 integrated into control unit 2, as shown in Fig. 2, take the form of acceleration sensors in the present exemplary

embodiment. Suitable acceleration sensors are described, for example, in chapter 3.2, 'Acceleration Sensor,' of the article "Hardware and Mechanics of Real Airbag Control Systems" published on the Internet page www.informatik.uni-dortmund.de/airbag/seminarphase/hardware_vortrag.pdf. Examples of suitable acceleration sensors include Bosch SMB060, Bosch PAS3, or Bosch UPF1. A suitable acceleration sensor may include, for example, a Bessel low-pass filter having a cutoff frequency of, e.g. 400 Hz. Crash sensors S1, S2, and S3 supply acceleration values aS1, aS2, and aS3, respectively, as output signals.

Crash sensors S2 and S3 are situated in a crash zone 3, which is bounded by the outer contours of motor vehicle 1 and a dotted line designated by reference numeral 7. In this context, crash zone 3 defines a region of motor vehicle 1, which, in the event of a collision of motor vehicle 1 with an obstacle, can be destroyed prior to a triggering time of airbag 15 and/or belt tensioner 16. Control unit 2 is situated with crash sensor S1 in a safety zone 4, which is bounded by a dotted line designated by reference numeral 8. In this context, safety zone 4 defines a region of the motor vehicle, which, in the event of a collision of motor vehicle 1 with an obstacle, is not destroyed or is only destroyed after a triggering time of airbag 15 and/or belt tensioner 16. Within the meaning of the present invention, a collision of motor vehicle 1 with an obstacle is, in particular, a collision from whose consequences an occupant protection device, such as airbag 15 or belt tensioner 16, should protect the occupant or occupants of motor vehicle 1. In the described exemplary embodiment, such a collision is a collision with a frontal component.

Actual crash zone 3 or actual safety zone 4 according to the above-mentioned definition is a function of the individual

design of the motor vehicle considered. Therefore, crash zone 3 and safety zone 4 of motor vehicle 1 cannot specify any universally applicable description of the position of crash zones and safety zones within the meaning of the above-mentioned definition. The position of crash zone 3 and safety zone 4 in Fig. 1 is used solely for explaining the present invention.

The occupant protection system further includes a belt sensor 11 for detecting if a seat belt is being used, and for outputting a corresponding belt information item MBELT. The occupant protection system further includes a seat-occupancy sensor 12 for detecting if, or how, a seat is occupied, and for outputting a corresponding seat-occupancy information item MSEAT. An example of a suitable seat-occupancy sensor is a pressure sensor integrated into the seat. Also suitable is an infrared scanning system described in chapter 3.3, "Interior Sensing," of the article "Hardware and Mechanics of Real Airbag Control Systems" published on the Internet page www.informatik.uni-dortmund.de/airbag/seminarphase/hardware_vortrag.pdf. Infrared scanning and fuzzy logic not only allow seat occupancy to be detected, but also allow a determination as to whether the seat occupant is an object, such as a purse, or a person. To this end, a line of, e.g. eight or more light-emitting diodes above the seat emit infrared light, and a CCD matrix of 64 pixels records the scene illuminated in this manner. These charged coupled devices, abbreviated CCD, are made up of photodiodes and amplifier elements in matrix configurations. In this context, incident light releases charge carriers in each instance. A signal generated in this manner is amplified, processed, and stored. This procedure is repeated at different angles, and the seat is scanned in this manner. Image-processing algorithms and fuzzy-logic

algorithms detect contours of objects and persons from these signals.

It may also be provided that the occupant-protection system include a control element 14 for activating or deactivating airbag 15. A corresponding switching signal is designated by reference character ONOFF.

Control unit 2 includes a control module 10 for calculating and outputting an ignition signal AIR for airbag 15 and/or an ignition signal BELT for belt tensioner 16 as a function of acceleration values aS1, aS2, and aS3, belt information item MBELT, seat-occupancy information item MSEAT, and switching signal ONOFF.

Fig. 3 shows an exemplary embodiment of control module 10. Control module 10 includes a triggering module 20 for calculating and outputting an ignition recommendation CRASH as a function of acceleration values aS1, aS2, and aS3. Control module 10 additionally includes a firing table 21 for calculating and outputting ignition signal AIR for airbag 15 and/or ignition signal BELT for belt tensioner 16 as a function of ignition recommendation CRASH, belt information item MBELT, seat-occupancy information item MSEAT, and/or switching signal ONOFF. Thus, it may be provided that ignition signal AIR only be equal to ignition recommendation CRASH when a corresponding seat is occupied by a person of a specific size, and that ignition signal AIR be otherwise equal to 0.

Both ignition recommendation CRASH and ignition signals AIR and BELT may be ignition signals within the meaning of the claims. Both ignition recommendation CRASH and ignition signals AIR and BELT may be a binary signal, e.g. one corresponding to the "FIRE/NO-FIRE" signal described in

DE 100 35 505 Al, the binary signal indicating whether an occupant protection device, such as an airbag and/or a belt tensioner, should be triggered. Both ignition recommendation CRASH and ignition signals AIR and BELT may also be a more complex signal. Both ignition recommendation CRASH and ignition signal AIR may be, for example, a more complex signal which indicates the degree (e.g. stage 1 or stage 2) to which airbag 15 should be fired. Both ignition recommendation CRASH and ignition signal AIR may additionally include, for example, a crash-severity parameter described in DE 100 35 505 Al or an occupant acceleration or occupant loading. It may be provided that both ignition recommendation CRASH and ignition signals AIR and BELT can indicate the location and/or the direction of a collision.

Fig. 4 shows an exemplary embodiment of triggering module 20. Triggering module 20 includes an analog-to-digital converter 25 for sampling acceleration value aS1 and outputting a sampled acceleration value as1, an analog-to-digital converter 26 for sampling acceleration value aS2 and outputting a sampled acceleration value as2, and an analog-to-digital converter 27 for sampling acceleration value aS3 and outputting a sampled acceleration value as3. The sampling frequency of the Δt of analog-to-digital converters 25, 26, and 27 may be, for example, 4 kHz. Triggering module 20 additionally includes (digital) integrators 31, 32, 33, 34, 35, and 36.

Using integrator 31, a pseudospeed value v0S1 at time t_0 is ascertained according to

$$v0S1 = \int_{t_0-\tau_0}^{t_0} as1 \cdot dt$$

where τ_0 is the length of a time interval $[t_0-\tau_0, t_0]$ or 40 (cf. Fig. 5). Time t_0 designates the current time, i.e. the current value of time t.

Using integrator 32, a pseudospeed value v1S1 at a time $t_0-\tau_1$ is ascertained according to

$$v1S1 = \int_{t_0-\tau_0-\tau_1}^{t_0-\tau_1} as1 \cdot dt$$

Using integrator 33, a pseudospeed value v2S1 at a time $t_0-\tau_2$ is ascertained according to

$$v2S1 = \int_{t_0-\tau_0-\tau_2}^{t_0-\tau_2} as1 \cdot dt$$

Using integrator 34, a pseudospeed value v3S1 at a time $t_0-\tau_3$ is ascertained according to

$$v3S1 = \int_{t_0-\tau_0-\tau_3}^{t_0-\tau_3} as1 \cdot dt$$

Using integrator 35, a pseudospeed value v0S2 at time t_0 is ascertained according to

$$v0S2 = \int_{t_0-\tau_0}^{t_0} as2 \cdot dt$$

Using integrator 36, a pseudospeed value v0S3 at time t_0 is ascertained according to

$$v0S3 = \int_{t_0-\tau_0}^{t_0} as3 \cdot dt$$

Fig. 5 and Fig. 6 illustrate the effect of integrators 31, 32, 33, 34, 35, and 36. In this context, Fig. 5 shows an example of a curve of (sampled) acceleration value as1 versus time t

in the event of a frontal collision of motor vehicle 1 with an obstacle. Fig. 6 shows an example of a curve of pseudospeed value v0S1 for τ_0 = 24ms.

In the exemplary embodiment shown in Fig. 6, τ_1 is 17 ms, τ_2 is 34 ms, and τ_3 is 51 ms. In one advantageous refinement, τ_1 may be 8 ms, τ_2 may be 16 ms, and τ_3 may be 24 ms.

Pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, and v0S3 are examples of time averages within the meaning of the present invention.

Triggering module 20 further includes a trigger generator 30 for generating ignition recommendation CRASH, shown in detail in Fig. 7. Trigger generator 30 includes a triggering relationship 30A for generating ignition recommendation CRASH as a function of pseudospeed values v0S1, v1S1, v2Sl, v0S2, and v0S3, a triggering relationship 30B for generating ignition recommendation CRASH as a function of pseudospeed values v0S1, v1S1, v2Sl, and v0S2, a triggering relationship 30C for generating ignition recommendation CRASH as a function of pseudospeed values v0S1, v1S1, v2S1, and v0S3, and a triggering relationship 30D for generating ignition recommendation CRASH as a function of pseudospeed values v0S1, v1S1, v2S1, and v3S1.

Trigger generator 30 additionally includes a selection module 38 for selecting a triggering relationship 30A, 30B, 30C, or 30D to use as a current triggering relationship 30E for generating current ignition recommendation CRASH as a function of pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, and v0S3. If selection module 38 detects that crash sensor S2 supplies acceleration values aS2 (and therefore that analog-to-digital converter 25 supplies sampled acceleration values as2), and that crash sensor S3 supplies acceleration values as3 (and

therefore that analog-to-digital converter 26 supplies sampled acceleration values as3), then selection module 38 selects triggering relationship 30A to use as a current triggering relationship 30E for generating current ignition recommendation CRASH.

If selection module 38 detects that crash sensor S2 supplies acceleration values aS2 (and therefore that analog-to-digital converter 25 supplies sampled acceleration values as2), but that crash sensor S3 does not supply any acceleration values as3 (and therefore that analog-to-digital converter 26 does not supply any sampled acceleration values as3), then selection module 38 selects triggering relationship 30B to use as a current triggering relationship 30E for generating current ignition recommendation CRASH.

If selection module 38 detects that crash sensor S3 supplies acceleration values aS3 (and therefore that analog-to-digital converter 26 supplies sampled acceleration values as3), but that crash sensor S2 does not supply any acceleration values as2 (and therefore that analog-to-digital converter 25 does not supply any sampled acceleration values as2), then selection module 38 selects triggering relationship 30C to use as a current triggering relationship 30E for generating current ignition recommendation CRASH.

If selection module 38 detects that crash sensor S2 does not supply any acceleration values aS2 (and therefore that analog-to-digital converter 25 does not supply any sampled acceleration values as2), and that crash sensor S3 does not supply any acceleration values as3 (and therefore that analog-to-digital converter 26 does not supply any sampled acceleration values as3), then selection module 38 selects triggering relationship 30D to use as a current triggering

relationship 30E for generating current ignition recommendation CRASH.

In one exemplary embodiment, the selection between triggering relationship 30A, 30B, 30C, or 30D as triggering relationship 30E is carried out by selecting between parameters P30A for defining triggering relationship 30A, parameters P30B for defining triggering relationship 30B, parameters P30C for defining triggering relationship 30C, and parameters P30D for defining triggering relationship 30D, to transfer to triggering relationship 30E.

Triggering relationships 30A, 30B, 30C, and 30D (or a part of triggering relationships 30A, 30B, 30C, and 30D) may, for example, take the form of a neural network, as shown in Fig. 8 as an exemplary embodiment for implementing triggering relationship 30A. The neural network shown in Fig. 8 includes five input nodes 50, 51, 52, 53, 54, six covered nodes 60, 61, 62, 63, 64, 65, and an output node 70, each input node 50, 51, 52, 53, 54 being connected to each covered node 60, 61, 62, 63, 64, 65, and each covered node 60, 61, 62, 63, 64, 65 being connected to output node 70. However, for reasons of clarity, Fig. 8 does not show all of the connections between input nodes 50, 51, 52, 53, 54 and covered nodes 60, 61, 62, 63, 64, 65.

Pseudospeed value v0S1 is the input variable input into input node 50, pseudospeed value v1S1 is the input variable input into input node 51, pseudospeed value v2S1 is the input variable input into input node 52, pseudospeed value v0S2 is the input variable input into input node 53, and pseudospeed value v0S3 is the input variable input into input node 54. The output variable from output node 70 is ignition recommendation CRASH.

Parameters P3OA, P3OB, P3OC, and P3OD may be, for example, the gains of nodes 50, 51, 52, 53, 54, 60, 61, 62, 63, 64, 65, and 70 of the neural network.

Details regarding neural networks may be found in U.S. 5,583,771, U.S. 5,684,701, and the documents "Techniques And Application Of Neural Networks", Taylor, M. and Lisboa, Ellis Horwood, West Sussex, England, 1993, "Naturally Intelligent Systems", Caudill, M. and Butler, G., MIT Press, Cambridge, 1990, and "Digital Neural Networks", Kung, S. Y., PTR Prentice Hall, Englewood Cliffs, NJ, 1993, cited in U.S. 5,684,701.

Table 1

```
/* Evaluation function */
int evaluate_Action(double *x)
{
     int CRASH;

     if (v0S3 < δ_v0S3 ) {
          if (v0S2 < δ_v0S2 ) {
               if (v2S1 < δ_v2S1 ) {
                    if (v0S1 < δ_v0S1 ) {
                         CRASH = 0;
                    } else {
                         if (v0S3 < δ_v0S3,2 ) {
                              CRASH = 0;
                         } else {
                              if (v0S1 < δ_v0S1,2 ) {
                                   if (v1S1 < δ_v1S1 ) {
                                        CRASH = 1;
                                   } else {
                                        CRASH = 0;
                                   }
                              } else {
                                   CRASH = 1;
                              }
                         }
                    }
               } else {
                    if (v0S2 < δ_v0S2,2 ) {
                         CRASH = 0;
                    } else {
                         if (v0S3 < δ_v0S3,3 ) {
                              CRASH = 0;
                         } else (
                              CRASH = 1;
                         }
                    }
               }
          } else {
               CRASH = 1;
          }
     } else {
          CRASH = 1;
     }
     return (CRASH);
}
```

As an alternative, triggering relationships 30A, 30B, 30C, and 30D (or a part of triggering relationships 30A, 30B, 30C, and 30D) may be designed, for example, as a sequence of

comparisons to limiting values. Table 1 shows such a sequence of comparisons to limiting values as an example of a possible implementation of triggering relationship 30A, the code shown in Table 1 having been automatically generated by a method explained with reference to Fig. 10. For the code shown in Table 1, t_1 is 4 ms, t_2 is 8 ms, and t_0 is 24 ms. Parameters P30A, P30B, P30C, and P30D may also be, for example, the code shown in Table 1.

Fig. 9 shows the code of Table 1, represented as a decision tree 80. In this context, reference numeral 81 denotes the inquiry as to whether v0S3 is less than a limiting value δ_{v0S3}. Reference numeral 82 denotes the inquiry as to whether v0S2 is less than a limiting value δ_{v0S2}. Reference numeral 83 denotes the inquiry as to whether v2S1 is less than a limiting value δ_{v2S1}. Reference numeral 84 denotes the inquiry as to whether v0S2 is less than a limiting value δ_{v0S1}. Reference numeral 85 denotes the inquiry as to whether v0S3 is less than a limiting value $\delta_{v0S3,2}$. Reference numeral 86 denotes the inquiry as to whether v0S1 is less than a limiting value $\delta_{v0S1,2}$. Reference numeral 87 denotes the inquiry as to whether v1S1 is less than a limiting value δ_{v1S1}. Reference numeral 88 denotes the inquiry as to whether v0S2 is less than a limiting value $\delta_{v0S2,2}$. Reference numeral 89 denotes the inquiry as to whether v0S3 is less than a limiting value $\delta_{v0S3,3}$.

Fig. 10 shows a method for manufacturing motor vehicle 1. To this end, a test prototype of motor vehicle 1 is initially produced in a step 90, crash sensors corresponding to crash sensors S1, S2, S3 for measuring the motion variable of motor vehicle 1 being installed in the motor vehicle. The test prototype of motor vehicle 1 is subjected to a crash test, where the output signals of the crash sensors corresponding to crash sensors S1, S2, S3 are measured. A database is constructed from these output signals and the output signals

of further crash tests. In this database, pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, v0S3 generated from the above-mentioned output signals of the crash sensors corresponding to crash sensors S1, S2, S3 are stored together with a triggering information item CRASHTRUE according to a method described in Fig. 4, Fig. 16, Fig. 17, and Fig. 18, the triggering information item indicating a setpoint ignition time or a setpoint triggering time. Triggering information item CRASHTRUE may indicate, for example, a setpoint ignition time of airbag 15.

Subsequent to step 90 is a step 91, in which triggering relationships 30A, 30B, 30C und 30D are generated on the basis of the data stored in the database. However, when triggering relationships 30A, 30B, 30C, and 30D are generated, pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, and v0S3 are disregarded in a training-suppression time interval around the setpoint triggering time of airbag 15 or belt tensioner 16, in a training-suppression time interval after the setpoint triggering time of airbag 15 or belt tensioner 16, or advantageously in a training-suppression time interval prior to the setpoint triggering time of airbag 15 or belt tensioner 16, as explained below with reference to Fig. 11, Fig. 12, Fig. 13, Fig. 14, and Fig. 15.

Fig. 11 shows the pseudospeed value according to Fig. 6, along with a corresponding training-suppression time interval t_{hole}, which is prior to a setpoint triggering time of airbag 15 or belt tensioner 16 designated by t_z. In this context, setpoint triggering time t_z is advantageously the time by which airbag 15 or belt tensioner 16 should be triggered at the latest. Training-suppression time interval t_{hole} is between 1 ms and 40 ms long, in particular between 2 ms and 10 ms long, and advantageously approximately 5 ms long. In the present

exemplary embodiment, training-suppression time interval t_{hole} is 5 ms.

Fig. 12 shows a section of Fig. 11 for the area between 0 ms and 40 ms. Fig. 13 shows corresponding triggering information item CRASHTRUE. Triggering information item CRASHTRUE is equal to 0 prior to setpoint triggering time t_z and equal to 1 after setpoint triggering time t_z, but, in the same way as the pseudospeed value of Fig. 12, it is disregarded in training-suppression time interval thole prior to setpoint triggering time tz for the generation of triggering relationships 30A, 30B, 30C, and 30D. This may be accomplished, for example, by removing the pseudospeed values and triggering information item CRASHTRUE from the data in training-suppression time interval t_{hole}.

Fig. 14 and Fig. 15 show an alternative procedure, which also disregards the pseudospeed values and triggering information item CRASHTRUE disregarded in training-suppression time interval thole, when triggering relationships 30A, 30B, 30C, and 30D are generated. In this context, the pseudospeed values are indeed also used in training-suppression time interval t_{hole} prior to setpoint triggering time t_z for generating triggering relationships 30A, 30B, 30C, and 30D, but a variable "no difference" is added to triggering information item CRASHTRUE in training-suppression time interval t_{hole} prior to setpoint triggering time t_z, the variable "no difference" indicating that both a 0 and a 1 outputted by triggering relationships 30A, 30B, 30C, and 30D during a training instance are correct for ignition recommendation CRASH. This means that regardless of whether triggering relationships 30A, 30B, 30C, and 30D output 0 or 1 as ignition recommendation CRASH during the training or learning within training-suppression time interval t_{hole}, it is assumed that the solution is correct, i.e. that ignition

recommendation CRASH is equal to triggering information item CRASHTRUE.

Using the database data modified according to the procedure described with reference to Fig. 12, Fig. 13, Fig. 14, and Fig. 15, triggering relationships 30A, 30B, 30C, and 30D are then automatically generated with the objective that ignition recommendation CRASH is equal to triggering information item CRASHTRUE for the utilized data. To automatically generate triggering relationships 30A, 30B, 30C, and 30D in an embodiment as a neural network shown in Fig. 8, tools conventional for this may be used for generating neural networks.

For example, the routine "treefit" from the "Statistics Toolbox" of the program "MATLAB 7" from Mathworks may be used for automatically generating triggering relationships 30A, 30B, 30C, and 30D in an embodiment as a sequence of comparisons represented in Table 1, or in an embodiment as a decision tree 80 shown in Fig. 9. This program can be acquired at the Internet address www.mathworks.com/company/aboutus/contact_us/contact_sales.html. Details about the "treefit" routine are shown at the Internet address www.mathworks.com/access/helpdesk/help/toolbox/stats/treefit.html.

The triggering relationship according to Fig. 9 and Table 1 does not take pseudospeed value v3S1 into account. It is taken into account in the learning process, but is disregarded during the generation of the code according to Table 1.

Step 91 is followed by an inquiry 92 as to whether triggering relationships 30A, 30B, 30C, and 30D generated in this manner are correct. To this end, triggering relationships 30A, 30B,

and 30D are tested, using the database entries not utilized in step 91. If triggering relationships 30A, 30B, 30C, and 30D are correct, then inquiry 92 is followed by a step 93. Otherwise, step 91 is repeated under different conditions.

In step 93, triggering relationships 30A, 30B, 30C, and 30D are implemented in control unit 2. Control unit 2 is then installed in motor vehicle 1, together with crash sensors S1, S2, and S3 and corresponding occupant protection devices such as airbag 15 or belt tensioner 16.

Although explained in connection with a binary triggering information item CRASHTRUE and a binary ignition recommendation CRASH, the present invention is also equally applicable to complex triggering information items and ignition recommendations. This is true for both the procedure described with reference to Fig. 12 and Fig. 13 and the procedure described with reference to Fig. 14 and Fig. 15.

In the preferred exemplary embodiment that is represented, pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, and v0S3, i.e. the time averages of (measured) acceleration values aS1, aS2, aS3, are used as input variables and training variables of triggering relationships 30A, 30B, 30C, and 30D. The (measured) acceleration values aS1, aS2, aS3 and sampled acceleration values as1, as2, as3 may be used in the same manner as pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, v0S3, as direct and not just indirect input variables and training variables of triggering relationships 30A, 30B, 30C, and 30D. This is also true for both the procedure described with reference to Fig. 12 and Fig. 13 and the procedure described with reference to Fig. 14 and Fig. 15. In a corresponding modification of the procedure described with reference to Fig. 12 and Fig. 13, (measured) acceleration values aS1, aS2, aS3 and/or scanned acceleration values as1,

as2, as3 are removed from the training data of triggering relationships 30A, 30B, 30C, and 30D, in the area of training-suppression time interval τ_{hole}.

Fig. 16 shows an exemplary embodiment of a triggering module 120 that is an alternative to triggering module 20. In this context, integrators 32, 33, and 34 are replaced by lag elements 132, 133, and 134, which are positioned in such a manner, that pseudospeed value v1S1 results as pseudospeed value v0S1 delayed by time τ_1, pseudospeed value v2S1 results as pseudospeed value v0S1 delayed by time τ_2, and pseudospeed value v3S1 results as pseudospeed value v0S1 delayed by time τ_3.

One example of a possible (simple) implementation of integrator 31 (that is also appropriately adapted for integrators 32, 33, and 34) is

$$vS1(i) = c \cdot \Delta t \sum_{j=i-\frac{\tau_0}{\Delta t}}^{i} as1(j)$$

where i is a running index for specifying current time t_0, and is a constant. In this case, pseudospeed values v0S1, v1S1, v2S1, and v3S1 are yielded, for example, in accordance with the following relationships:

$$v0S1 - vs1(i)$$

$$v1S1 = vS1(i - \frac{\tau_1}{\Delta t})$$

$$v2S1 = vS1(i - \frac{\tau_2}{\Delta t})$$

and

$$v3S1 = vS1(i - \frac{\tau_3}{\Delta t}).$$

Fig. 17 shows an exemplary embodiment of a triggering module 220 that is an alternative to triggering module 20. In this context, integrators 32, 33, and 34 are replaced by integrators 232, 233, and 234. In this context, pseudospeed value v1S1 is ascertained via integrator 232 according to

$$v1S1 = \int_{t_0-\tau_1}^{t_0} as1 \cdot dt$$

Using integrator 233, a pseudospeed value v2S1 at time t_0 is ascertained according to

$$v2S1 = \int_{t_0-\tau_2}^{t_0} as1 \cdot dt$$

Using integrator 234, a pseudospeed value v3S1 at a time t_0 is ascertained according to

$$v3S1 = \int_{t_0-\tau_3}^{t_0} as1 \cdot dt$$

In triggering module 20 according to Fig. 4 and triggering module 120 according to Fig. 16, the time intervals differ in their position. However, in triggering module 220 according to Fig. 17, the time intervals differ in their length. It may also be provided that time intervals differ in their length and in their position. A corresponding exemplary embodiment is shown in Fig. 18. Fig. 18 shows an exemplary embodiment of a triggering module 320 that is an alternative to triggering module 220. In this context, integrator 234 is replaced by an integrator 334, with the aid of which a pseudospeed value v3S1 at a time $t_0-\tau_4$ is ascertained according to

$$v3S1 = \int_{t_0-\tau_3-\tau_4}^{t_0-\tau_4} as1 \cdot dt$$

The present invention produces particularly robust triggering of airbags and belt tensioners.

Although explained in the exemplary embodiments with regard to airbags and belt tensioners for a frontal collision, the present invention should not, of course, be restricted to this case. The present invention is also applicable to side airbags and other occupant protection systems. In one implementation for side airbags, crash sensors S2 and S3 may be situated, for example, in the B-pillar. It may be provided that at least one pseudospeed value over at least one additional time interval be calculated for crash sensor S2 and/or crash sensor S3, as well.

Control unit 2 may also be a distributed system. A control unit within the meaning of the present invention does not have to be accommodated in a single housing. A control unit within the meaning of the present invention may also be an individual chip or a printed circuit board.

To the extent that decision trees are mentioned in connection with the generation of ignition recommendation CRASH, these may also be replaced by regression trees, association tables, rule sets, supervector machines, or other machine-learning procedures.

Instead of motion variables or their average values, differences of motion variables, average values of these differences, and/or differences of average values may also be used. Thus, e.g. a subtractor may be provided in front of integrators 31, 32, 33, 34, 35, 36, 232, 233, 234, and 334 in Fig. 4, Fig. 16, Fig. 17, and/or Fig. 18, so that instead of sampled acceleration values as1, as2, as3, differential values Δas1, Δas2, Δas3 are input variables of integrators 31, 32, 33, 34, 35, 36, 232, 233, 234, and 334; Δas1 being equal to

difference as1-as2, Δas2 being equal to difference as1-as3, and Δas3 being equal to difference as2-as3. In addition, it may be provided that differential value Δas1 be processed in the same manner as sampled acceleration value as1 in Fig. 4, Fig. 16, Fig. 17, and/or Fig. 18, that differential value Δas2 be processed in the same manner as sampled acceleration value as1 in Fig. 4, Fig. 16, Fig. 17, and/or Fig. 18, and/or that differential value Δas3 be processed in the same manner as sampled acceleration value as2 in Fig. 4, Fig. 16, Fig. 17, and/or Fig. 18. In this case, the number of integrators and the number of input variables are to be appropriately adapted to trigger generator 30.

Differences may also be time differences. Thus, it may be provided that differential values Δas1, Δas2, Δas3 be used in place of sampled acceleration values as1, as2, as3 as input variables of integrators 31, 32, 33, 34, 35, 36, 232, 233, 234, and 334, Δas1(t) being equal to difference as1(t)-as1(t-τ), Δas2 being equal to difference as2(t)-as2(t-τ) or to difference as2(t)-as3(t-τ), and Δas3 being equal to difference as3(t)-as3(t-τ) or to difference as3(t)-as2(t-τ).

In accordance with above-mentioned variants with regard to the calculation of a difference, motion variables within the meaning of the present invention may also be differences of motion variables, when they are used as input variables. One may proceed in an analogous manner with pseudospeed values v0S1, v1S1, v2S1, v3S1, v0S2, and v0S3. Accordingly, average values of motion variables within the meaning of the present invention may also be differences of average values of motion variables or average values of differences of motion variables, when they are used as input variables.

List of Reference Numerals

1	motor vehicle
2	control unit
3	crash zone
4	safety zone
5, 6	leads
7, 8	dotted line
10	control module
11	belt sensor
12	seat-occupancy sensor
14	control element
15	airbag
16	belt tensioner
20, 120, 220, 320	triggering module
21	firing table
25, 26, 27	analog-to-digital converter
30	trigger generator
30A, 30B, 30C, 30D, 30E	triggering relationship
31, 32, 33, 34, 35, 36, 232, 233, 234, 334	integrator
38	selection module
40	time interval
50, 51, 52, 53, 54	input node
60, 6l, 62, 63, 64, 65	covered node
70	output node
80	decision tree
81,82,83,84, 85, 86, 87, 88, 89, 92	inquiry
90, 91, 93	step
132, 133, 134	lag element

AIR, BELT	ignition signal
aS1, aS2, aS3, as1, as2, as3,	acceleration value
CRASH	ignition recommendation
CRASHTRUE	triggering information item
ONOFF	switching signal
MBELT	belt information item
MSEAT	seat-occupancy information item
P30A, P30B, P30C, P30D	parameter
S1, S2, S3	crash sensor
t	time
t_0	current time
t_z	setpoint triggering time
v0S1, v1S1 v2S1, v3S1 v0S2, v0S3	pseudospeed value
τ_0	length of a time interval
τ_0, τ_1, τ_2, τ_3	length of a time interval or time (delay)
τ_{hole}	training-suppression time interval